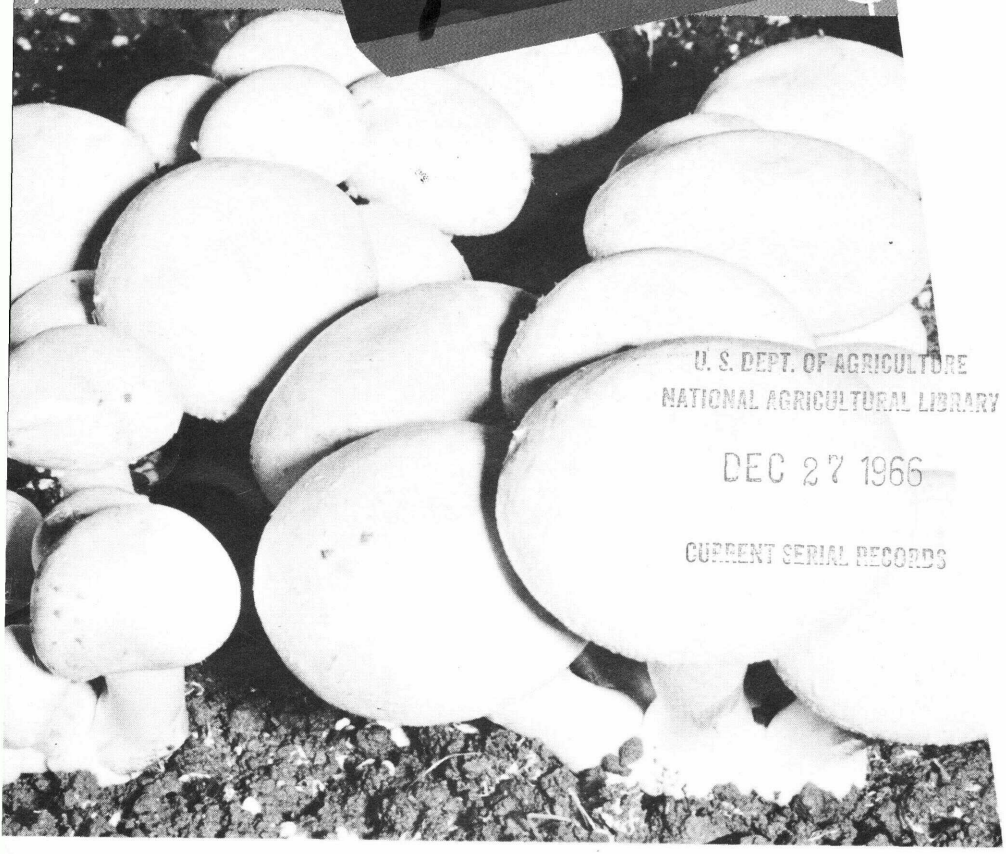
MUSHROOM GROWING in the UNITED STATES



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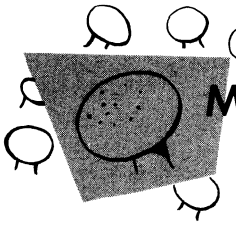


MUSHROOM GROWING IN THE UNITED STATES

By **EDMUND B. LAMBERT**,[1] *pathologist, Crops Research Division, Agricultural Research Service*

Individuals seeking information on mushroom growing are frequently misled into believing that it is an occupation offering unusual opportunities for profit with little experience and a small capital investment. Often a beginner spends a considerable part of his savings on a mushroom-growing venture before realizing that he is entering a well-established and competitive field with a low margin of profit.

The purpose of this bulletin is to give prospective growers information on the requirements for commercial mushroom growing and to point out the obstacles beginners are likely to encounter. Cultural practices are described briefly to give the novice some idea of the complexity of mushroom growing. A short discussion of amateur mushroom growing at home is included since many inquiries are made by garden enthusiasts who would like to grow mushrooms in the winter as a continuation of their summer gardening activities.

The beginner will almost certainly be disappointed if he expects to make easy profits during the years he is learning to grow mushrooms. Considerable physical labor is required for the preparation of mushroom beds, perhaps more than in any other horticultural venture. To obtain profitable yields the grower must have adequate facilities, a thorough knowledge of the principles of mushroom growing, and a skill that can be developed only through long experience.

The minimum size of a mushroom-growing establishment required to make a livelihood for a family is one with about 20,000 square feet of bed space. The cost of building and equipping a plant of this size is approximately $50,000. Additional working capital of about $10,000 is required to pay for the manure, spawn, and labor needed to prepare the beds before salable mushrooms are obtained.

The Mushroom Industry

Mushroom culture is not new. It was practiced in France and England for many years before it was introduced into the United States in the latter part of the 19th century. The first mushroom-growing center in this country was in the vicinity of New York City, extending out onto Long Island. About 1890, greenhouse operators near Kennett Square, Pa., started to grow mushrooms in the unused spaces under the greenhouse benches. Soon many farmers in the vicinity were growing mushrooms in idle space in barns, sheds, and cellars; and by the turn of the century special sheds were being constructed for the sole purpose of growing mushrooms. A large part of the industry still is concentrated in Pennsylvania, Delaware, and New York. However, climatic and soil conditions permit the com-

[1] Retired.

mercial culture of mushrooms in all States except those of the deep South, and now growers are located in the vicinity of all the large cities in the northern States. The comparatively high cost of artificial refrigeration has, with a few exceptions, prevented the development of large establishments in the southern States.

Mushroom culture has made rapid strides in the United States during the past quarter century, both in the improvement of cultural methods and in total production. At first, crop failures were frequent and an average production of one-half pound per square foot was considered a good yield. Following the introduction in 1918 of pure-culture spawn grown from selected spores, and the practice of pasteurizing the beds before planting the spawn, the average yield soon increased to 1 pound per square foot and was in 1960 between 1½ and 2 pounds per square foot per crop.

According to estimates made by representatives of the industry over 90,000,000 square feet of bed space was planted to mushrooms annually. The total annual production has been estimated at 160,000,000 pounds. Between 15,000 and 20,000 workers are engaged in growing and in canning mushrooms. Several million dollars are spent annually for horse manure and materials for making artificial compost. Most of the growers use mechanical equipment such as trucks, tractors, conveyors, and loaders. The total capital worth of all businesses depending on mushroom growing has been estimated at well over $50,000,000.

Nature of the Mushroom and Its Nutritional Value

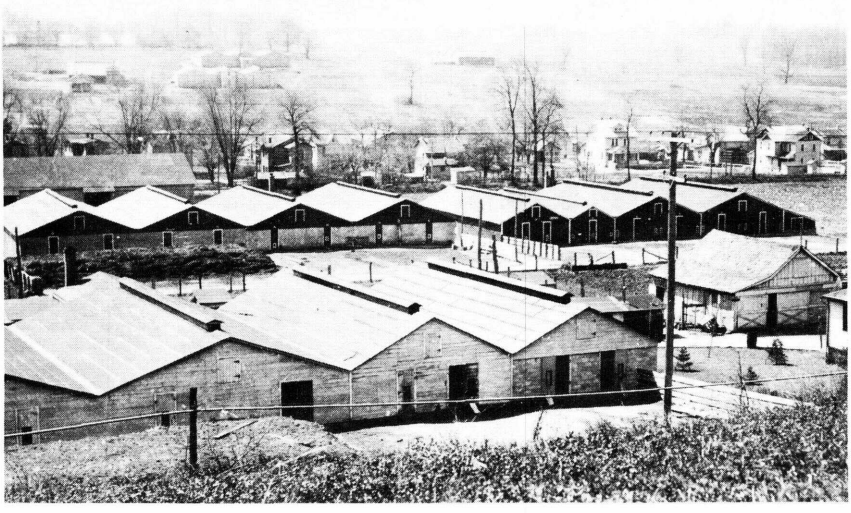
Only one type of mushroom is cultivated in the United States—a horticultural adaptation of the common field mushroom. The portion of the mushroom appearing above ground is the edible mushroom of commerce. When mature, it produces and liberates spores, microscopic reproductive bodies similar in function to seeds. All parts of the mushroom are edible. The flesh of the stem is nearly as soft as that of the cap and there is no protective covering such as the bark on the stems of higher plants or the waxy "bloom" on some fruits and leaves. The rootlike part of the mushroom plant grows extensively underground before the edible portion is formed. It consists of a white cottony mold which permeates partly decomposed organic matter to seek nutrients in a manner similar to the way roots of higher plants permeate the soil. A fundamental difference between mushrooms and green plants is that the latter can manufacture their own carbohydrate food, whereas mushrooms cannot. Mushrooms are grown in organic compost containing carbohydrates in addition to the minerals and nitrogen required by green plants. They cannot be grown in a liquid medium (hydroponics), because the presence of carbohydrates in the liquid will stimulate the growth of airborne contaminating molds which soon crowd out the "mushroom mold."

Cultivated mushrooms have a place in the average American diet, not only on the basis of their flavor, but also because of definite food values which they possess. They contain much less protein than meat and fish, but mushrooms compare favorably with most fresh vegetables in protein content and are good sources of vitamins and of minerals such as iron and copper. Mushrooms are an excellent plant source

of riboflavin and nicotinic acid and a good source of pantothenic acid. They also contain appreciable amounts of thiamin and biotin. These vitamins are well retained during cooking and in canned, dehydrated, and frozen mushrooms.

Sites for Mushroom Growing

The climate in the United States is not suitable for the commercial production of mushrooms out of doors. To obtain satisfactory yields they must be grown in enclosed rooms arranged to permit the regulation of temperature, humidity, and ventilation. Various types of structures have been used for growing mushrooms but the type which has proved most satisfactory is a long, narrow building containing 10 or 12 shelf beds. These houses are 65 feet long, 20 feet wide, and about 15 feet high. The beds are arranged in 2 tiers, 5 or 6 beds high, and are usually 5 feet wide. A house of this size contains about 3,600 square feet of bed space and is called a "single house." Frequently,



Standard mushroom houses near Toughkenamon, Pa.

two such units are built together under a single roof, and in this case are termed a "double house." A moderate-size mushroom establishment consists of at least three such double houses. They are usually placed on a hillside in such manner that the beds may be filled from the higher part of the site without special equipment for elevating the manure.

Since 1935, a few growers have adopted a system of culture that makes use of small movable trays of compost instead of fixed beds. With this system, sometimes called the "two zone" system, two separate series of rooms are needed, one for pasteurizing the manure and growing "spawn" in the beds, and the other for growing the mush-

rooms. The surface of the compost in the trays is usually covered with a thin layer of soil at the time the trays are transported from the spawning rooms to the growing rooms. This soil covering is called the "casing" and is used in both bed and tray systems of culture.

The tray system is especially well adapted to situations in which large areas of suitable space are available in abandoned buildings, caves, mines, et cetera, that can be cheaply modified to provide year-

Tray culture in an abandoned limestone mine near Pittsburgh, Pa.

round conditions favorable for the growing phase of mushroom culture, but which would be difficult or impracticable to heat to pasteurizing temperatures. In such situations comparatively small buildings are constructed to provide the necessary pasteurizing rooms. In favorable situations the cost of building these small pasteurizing rooms and adapting the available growing space for culture may be considerably less than the cost of building an equivalent area of standard mushroom houses. This advantage has enabled a few growers using underground limestone or gypsum mines to develop very large installations. The two largest mushroom plants in the United States, one on the Hudson River near Albany and the other near Butler, Pa., are installations of this type. These plants produce several tons of mushrooms per day.

Preparation of Compost

Mushroom growers traditionally have used composted horse manure to fill their beds, but in recent years a satisfactory synthetic compost, prepared from a mixture of corn cobs and hay supplemented with fertilizer containing nitrogen, phosphorus, and potash, has been used.

Horse manure is obtained principally from racing stables and riding

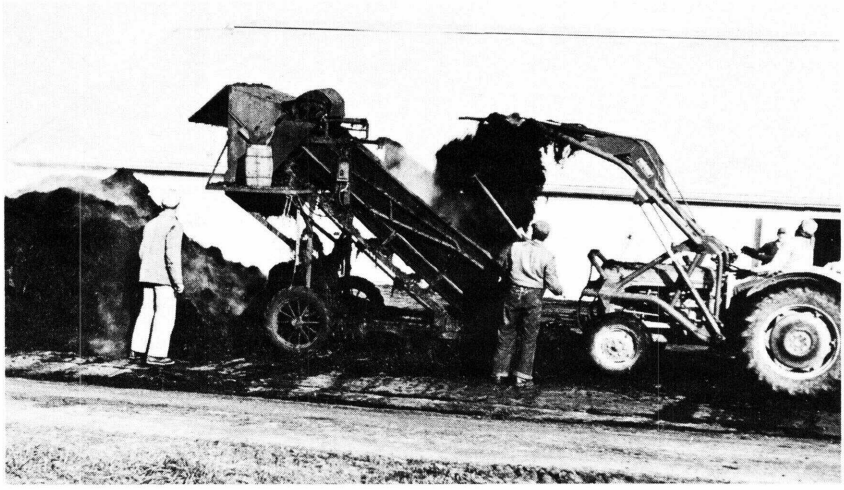
stables. Growers usually mix manure from different sources so as to obtain a more or less standard mixture with a medium content of straw. When the manure is received in the spring or early summer it is usually stored in large heaps like haystacks to retard decomposition until ready for use.

The first step in the composting of the manure for mushroom culture is to place it in heaps 8 or 10 feet wide by approximately 7 feet

Piling stable manure in storage heaps.

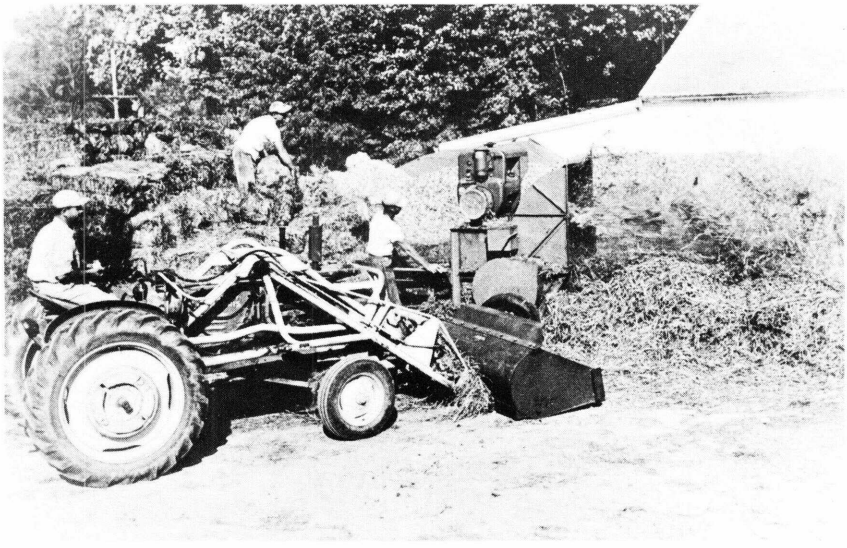
high, and as long as is convenient, meanwhile wetting it as thoroughly as possible. Gypsum is added throughout the heap as it is built at the rate of about 30 pounds per ton of manure. Two to four days after the heap has been established it is broken up, wetted again, aerated, and mixed thoroughly by passing it through a special "turning" or mixing machine. This procedure is repeated three times at intervals of 4 or 5 days. At the end of this time the compost is much more uniform in moisture than at first, and has been partially broken down by fermentation.

In some cases growers have found it advantageous to supplement very strawy horse manure with material such as brewers' grain, cottonseed meal, or poultry manure that is medium high in nitrogen content. Brewers' grain is usually added to strawy manure at the rate of approximately 100 pounds per ton of manure; one-third of this amount is applied during the second turning, one-third during the third turning, and the remainder during the fourth turning. Cottonseed meal is usually used at the rate of 60 pounds per ton, and dried poultry manure at the rate of 150 pounds per ton.



Preparing mushroom compost with a tractor fork and machine for wetting and aerating.

Many growers in eastern Pennsylvania are using synthetic compost made according to a procedure developed cooperatively by J. W. Sinden of the Pennsylvania State University, the Boy-Ar-Dee Mushroom Company at Milton, Pa., and the Butler Mushroom Company at West Winfield, Pa. The following is approximately the list of materials required for making compost for filling a double house: 15 tons of corn cobs, 7 tons of meadow hay, 4 tons of clover or alfalfa hay, one-half ton of gypsum, 500 pounds of ammonium nitrate, 500 pounds of muriate of potash, 1½ tons of dried brewers' grain or like amount of dried poultry manure, and a total of 10,000 to 11,000



Preparing synthetic compost with corn cobs and chopped hay.

gallons of water to give the desired moisture content. Modifications of this formula are being tried experimentally to improve crops, but the proportions as listed above have consistently given good results.

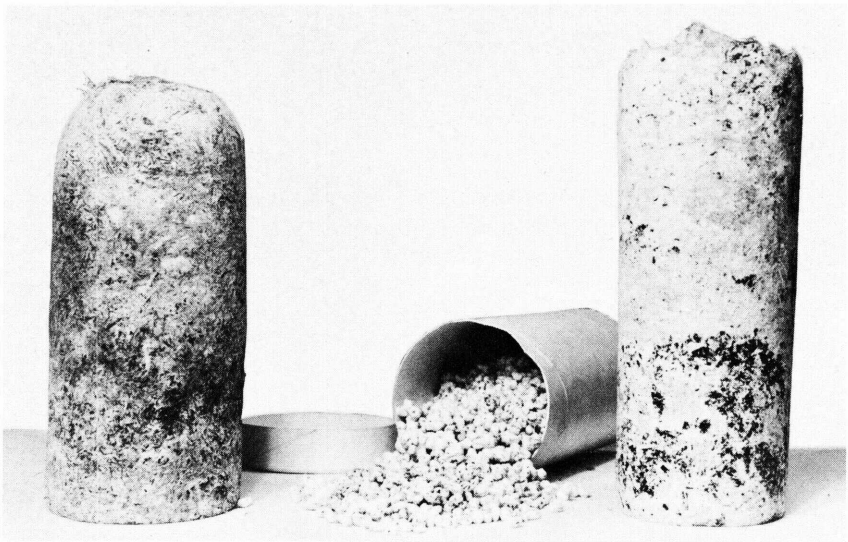
This material is composted in essentially the same manner as horse manure except that it requires a great deal more water than horse manure does throughout the composting process. Corn cobs and hay will hold more water than horse manure does without being excessively wet. When the heap is first made the corn cobs and hay are placed alternately in layers about 4 inches thick and given all the water they will take without water running out of the heaps. Two days later the mixture is passed through a turning machine and wet again with all the water it will take. Three or four days later the pile is again turned with the machine and wet thoroughly. The chemicals are now added to the top of the pile and in another 4 days the pile is turned again, mixing the chemicals and wetting the material as it is turned. It is turned again in 4 or 5 days and made ready for filling the houses.

Pasteurizing

After the last turning the compost should be in long, narrow, well-aerated heaps, not wider than about 8 feet. It should have a water content between 70 and 75 percent. The beds are filled to a depth of 6 to 10 inches, a ton of moist compost filling approximately 100 square feet of bed. When all of the beds are filled with compost the doors and ventilators are closed and the temperature in the room is allowed to rise as a result of the heat generated in the manure, assisted with live steam, until the temperature in the compost is between 135° and 140° F. This temperature is maintained until all odor of ammonia has left the compost and its pH value is 8.2 or below. The beds are watered during pasteurizing so that they will contain about 65 percent moisture at the end of the pasteurizing period. When the pasteurizing is completed, usually after 4 to 6 days, the room is ventilated to bring the temperature down between 75° and 80° F. This temperature is suitable for "spawning"—the period of growth that includes the planting of the mushroom spawn and the development of the fungus in the compost before the mushrooms appear. This prolonged pasteurizing period in the house is an essential part of the composting procedure and, although there are several modifications in the temperature sequence followed by different growers, all are agreed that some form of pasteurizing must be carried out to control harmful fungi, insects, and nematodes, and to obtain consistently high yields.

Growing Procedure

The propagating material used by all growers for planting the beds is called spawn. It is usually prepared on one of three materials—grain, manure, or tobacco stems. There are several well established spawn makers who have mastered the intricate pure-culture technique necessary for preparing propagating material from the spores of the mushrooms. Nearly all growers prefer to purchase spawn from these pure-culture spawn makers rather than attempt to prepare it themselves.

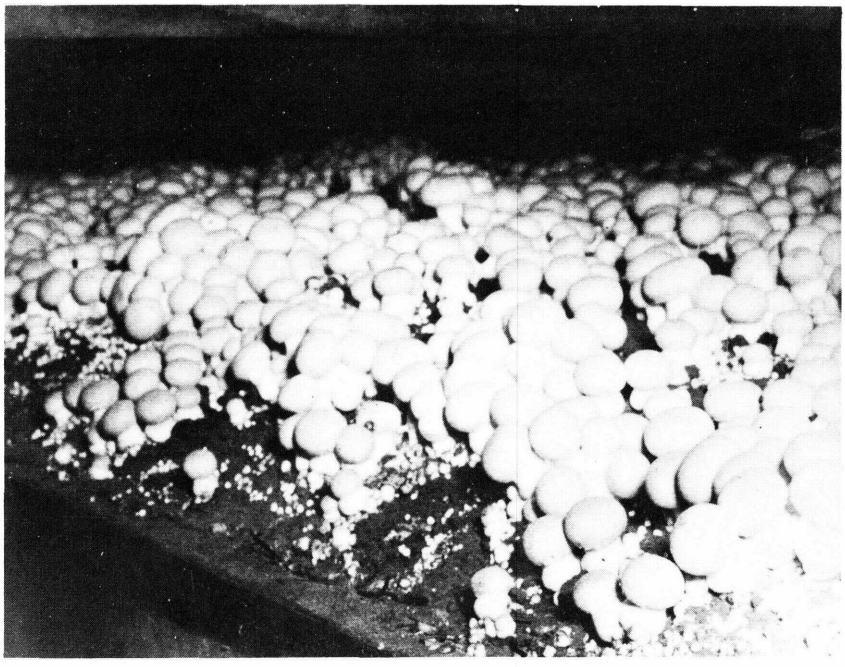


Mushroom spawn prepared on sterile manure, rye grain, and tobacco stems.

Spawn is usually broadcast over the surface of the beds. The spawn is allowed to grow in the bed for about 7 days while the temperature is held at approximately 70° F. The bed temperature is then lowered to between 65° and 70° while the spawn continues to grow for an additional week or two. At the end of this period the cottony growth of mushroom spawn will have permeated most of the upper 3 inches of the bed. Some ventilation is provided during the growth of the spawn and the surface layer of manure is watered lightly to retain an appropriate moisture content of about 65 percent throughout all of the compost in the bed.

After the spawn has "run" in the bed 2 or 3 weeks, a layer of about an inch of "casing" soil is spread over the surface of the bed. The soil should be a loam that is neither too sandy in texture nor too high in clay, and neutral in reaction. If the soil to be used for casing is acid, it is usually neutralized by adding ground limestone. This soil is kept moist with very light watering until the mushrooms begin to form. The first mushrooms will appear all over the surface of the bed about 3 weeks after casing.

At the time mushrooms appear, the temperature is lowered to a chosen point between 50° and 65° F. If a slowly developing crop with a long harvest season is desired, the temperature is held at about 50°. If more rapid development with a short harvest season is desired, the temperature is held at about 62°. Mushrooms will continue to develop for 2 or 3 months, depending on the temperature. They usually appear in sudden outbreaks at intervals of about a week. These outbreaks are called "flushes" or "breaks" and are followed by



A good "break" of mushrooms growing on a standard shelf bed.

periods with only a few mushrooms appearing on the bed. Usually additional water is applied to the surface of the bed at the time each break is appearing. The soil moisture must be maintained at a rather high level to obtain maximum crops.

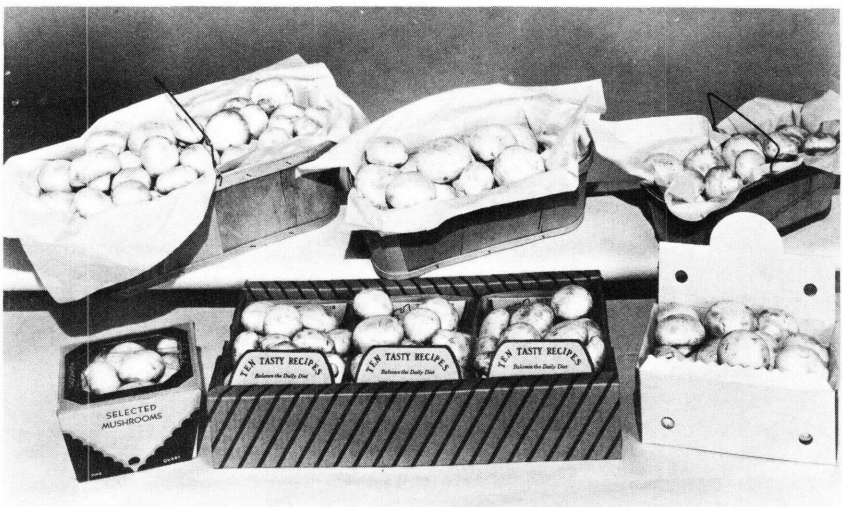
During the growth of the mushrooms the humidity of the air in the mushroom house must be maintained above 70 percent to prevent drying out of the mushroom caps. At the same time considerable ventilation must be supplied to assure maximum yields. Usually it is advisable to give as much ventilation as possible without interfering with temperature and humidity control, or causing a cracking of the surface of the mushrooms.

There are many diseases and pests of mushrooms which tend to reduce the yields and render the mushrooms unsalable. Frequently these pests are the cause of partial or complete crop failure. While the success of a commercial grower depends largely on his ability to exclude or control these pests, they are too numerous and the control measures too intricate to be discussed here.

More detailed information on all phases of mushroom growing is available in textbooks and other publications listed in a mimeographed paper entitled "Sources of Mushroom Spawn and Additional Information" distributed by the Information Division, Agricultural Research Service, U.S. Department of Agriculture, Hyattsville, Md. 20781.

Harvesting and Marketing

Mushrooms are "picked" just before the cap expands to expose the "gills." In this stage of growth they may range from 1 inch to 3 inches in diameter. After the mushroom or clump of mushrooms has been picked, the remaining fleshy mushroom tissue is carefully removed from the soil and the hole filled with fresh soil. Large numbers of young "button" mushrooms from one-eighth to three-eighths inch in diameter die off after the larger mushrooms are removed, even on normal beds, presumably because harvesting the large mushrooms breaks many of the strands connecting the young mushrooms with their supply of nutrients in the compost. With a little practice these dead or damaged mushrooms are easily distinguished from healthy buttons and are removed from the bed to prevent spread of decay. This job must be done thoroughly at frequent intervals in order to assure maximum crops.



Mushrooms packaged for market.

When the mushrooms are to be sold on the fresh market the stumps are usually cut off at the time of picking and the mushrooms are sorted according to size, freedom from blemishes, and certain other requirements. They are packed in 7-ounce or 1-pound cartons, or in 3-pound baskets. In most large cities they are sold by fruit and vegetable produce dealers. These merchants receive the mushrooms on consignment, set the wholesale price in accordance with supply and demand, and charge the grower a 10-percent commission for their services. The daily wholesale price of fresh mushrooms is usually quoted in the local newspapers.

In some localities the grower may have a choice between sending his mushrooms to produce dealers, to canneries, or to soup makers. The demand for canned mushrooms has increased in recent years until, at the present time, most of the mushroom crop is sold in cans. One-third is marketed as fresh mushrooms, one-third as canned mush-

rooms, and the remainder is processed in soup. The sale of both canned mushrooms and mushroom soup has played a very important part in the nationwide acceptance of mushrooms as an everyday food product. National advertising of mushroom soup has once and for all dispelled from the mind of the average housewife the unfounded fear of mushroom poisoning. This product quickly won popularity since it is a relatively inexpensive item of good quality. The processing industries also serve as important and indispensable factors for stabilizing the price of mushrooms in large production centers.

Drying and Freezing

Mushrooms can be successfully dried by placing them on wire trays one layer deep and passing a rapid current of warm air over them. If the temperature of the mushrooms is raised to 130° F. for a few hours during drying, all insects infesting the mushrooms will be killed. When thoroughly dry and free from insects they will keep in good condition more than a year. If dried in a vacuum while frozen, they retain full flavor. If exposed to moisture or high humidity, they deteriorate rapidly as a result of enzymic changes or the invasion of insects and decay organisms.

Over a period of 25 years sporadic attempts have been made by large mushroom growers in the United States to market the common cultivated variety in a dried or powdered form. For various reasons, such as extreme shrinkage in weight during drying—10 to 1—and competition with the fresh or canned product, these commercial ventures in mushroom drying have not been found profitable in this country. The dried mushrooms sold in the United States are imported from Europe and the Orient. They are not the same kind as are cultivated in this country. Those from Europe are wild mushrooms gathered from the fields and those from the Orient are of different kinds cultivated by entirely different methods than those used in the United States.

When mushrooms are quick frozen in the raw state they retain their full flavor and attractiveness for only about a month. After this the tissue turns black due to the action of oxydizing enzymes. On the other hand, they will keep a long time in the frozen state if blanched by steaming or boiling before freezing, or frozen by quick freezing methods.

Costs and Returns

The mushroom grower encounters most of the economic difficulties that confront the producer of other perishable crops. Under present market conditions there is no assurance that a grower will be able to raise mushrooms at a profit.

Because yields are highly variable, the cost of producing a pound of mushrooms is difficult to estimate. The most important items of cost are: Interest on the investment, depreciation, manure or synthetic compost, soil, spawn, labor for composting, filling, spawning, casing, picking and packing for market, and emptying the beds.

The price differs from one locality to another and from one season to another. It is usually beyond the grower's control. Because his product is highly perishable, he must send it to market on the day it

is harvested and cannot ship it long distances. Warm spells in the early fall and late spring may greatly increase the supply of mushrooms for several days at a time by raising the temperature in mushroom houses. The temperature rise is reflected in an increased rate of growth of the mushrooms and in the production of a larger proportion of small mushrooms. In congested centers of mushroom growing, this usually occurs in hundreds of mushroom houses at the same time, and the grower often finds himself in the untenable position of producing the most mushrooms when the price is below the cost of production.

Mushroom Growing at Home

The cost of the material and labor for mushrooms produced at home may be slightly greater than the cost of mushrooms purchased at the local store; however, mushroom culture at home offers a fascinating winter hobby, with a reward of freshly picked mushrooms for family and friends.

Most amateurs will find it very difficult and disagreeable to prepare a suitable mushroom compost from a small heap of manure. Without the facilities of the commercial grower for pasteurizing, the compost prepared by an amateur will frequently be unsuited for mushroom culture because of the presence of harmful fungi, nematodes, and insect pests.

In recent years a few nurserymen and seedsmen have been offering for sale trays containing mushroom compost especially prepared for home use, which appear to be the solution to many of the problems of growing mushrooms at home. It is recommended that the amateur grower purchase these prepared trays instead of attempting to make his own mushroom compost. They are prepared for the nurserymen and seedsmen by commercial mushroom growers who are equipped to compost manure economically on a large scale, to pasteurize the compost effectively, and grow spawn in the trays. Full directions for growing mushrooms are furnished along with the trays. If the directions are carefully followed, and if the trays are placed in a cool, damp location, moderate yields can be expected, usually between one-half pound and a pound per square foot of tray space.

Once the mushrooms begin to appear on the trays they will continue to develop for about 60 days. As mushrooms do not need light for normal development, they can be grown in a basement room or shed where it would be impossible to grow green plants. Growing space must be available in which the temperature can be maintained under 65° F., and the humidity of the air kept moderately high. Some ventilation is necessary, but the number of air changes normally occurring in the average cellar room will usually be sufficient for a few square feet of mushroom bed.

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CHECK up on these accident hazards around your farm . . .

√ Is farmyard clear of tools, broken glass, loose strands of barbed wire, nail-studded boards?

√ Are water tanks, cisterns, and wells protected?

√ Are ladders and steps in good repair?

√ Are pitchforks, rakes, shovels, and other sharp tools kept in racks?

√ Are electric circuits and appliances in good condition?

√ Is unused lumber carefully stacked?

√ Are buildings and fences in good repair?

clean up your farm

to make it attractive and SAFE